

USE OF TAUROLIDINE AND/OR TAURULTAM FOR TREATMENT OF
ABDOMINAL CANCER AND/OR FOR PREVENTION OF METASTASES

BACKGROUND OF THE INVENTION

The present application is a continuation-in-part of U.S. Serial No. 09/493,797, filed January 28, 2000, which is a §371 of International Application No. PCT/GB98/02311, filed July 30, 1998.

5 The present application also claims the benefit of U.S. Provisional Application Serial Nos. 60/239,916, filed October 13, 2000, 60/246,100, filed November 7, 2000 and 60/253,138, filed November 28, 2000.

FIELD OF THE INVENTION

10 The present invention relates to cancer treatment.

DESCRIPTION OF THE BACKGROUND ART

Prior art cancer treatments typically involve surgical removal of the cancerous tumor and subsequent treatment with anti-cancer drugs or radiation.

15 SUMMARY OF THE INVENTION

Taurolidine and/or taurultam is administered during and after surgery to treat abdominal cancer.

DETAILED DESCRIPTION OF THE INVENTION

20 The present invention relates to a method of treating abdominal cancer comprising performing a surgery on a patient's abdomen by forming a surgical opening in the patient's abdomen, and surgically removing a cancerous tumor from the patient's abdomen through the surgical opening. Prior to closing the surgical opening, taurolidine, taurultam or a mixture thereof is
25 administered to the patient's abdomen so as to treat cancer in the patient's abdomen. After the surgical opening in the patient's abdomen is closed, additional taurolidine, taurultam or a mixture thereof is administered to the patient. In certain embodiments, taurolidine, taurultam or a mixture thereof also is administered
30 to the patient prior to performing the surgery to remove the tumor. Exemplary abdominal cancers include, but are not limited to, colon cancer, rectal cancer, pancreatic cancer, stomach cancer and lung cancer. Taurolidine, taurultam and mixtures thereof have been found to have anti-angiogenic activity when administered pre-
35 operatively, peri-operatively and post-operatively in conjunction with transabdominal oncology surgery. In accordance with one

embodiment, the taurolidine and/or taurultam may be administered in combination with administration of 5-fluorouracil (5-FU), wherein the 5-FU is administered at a dosage within the range of about 0.1 - 1000 mg per dosage unit.

5 This invention also relates to a method for preventing metastases, in particular to a method for preventing metastatic growth of malignant tumors. More particularly it relates to a method for preventing metastatic growth following surgery, and especially minimally invasive abdominal surgery, such as
10 endoscopic, e.g. laparoscopic surgery.

Malignant tumors within the body, and particularly the abdomen are frequently removed surgically. The exploration and excision of tumors by major invasive surgery has been used for many years, but, more recently, minimal invasive surgery has
15 increasingly been used.

A wide range of indications of malignant tumors exist for which invasive surgery, such as laparotomy or laparoscopy, may used. These include, but are not restricted to, the following: oesophagus carcinoma (plaster cell carcinoma, adenocarcinoma) and
20 cardiacarcinoma; malignant degenerative ulcer; carcinoma of the stomach, antrum or corpus, malign adenoma of island cells, resection or total gastrectomy; carcinoma of the gall duct or distal choledochus; carcinoma of the pancreas head, papilla, corpus or cauda; carcinoma of the small or large intestinal tract, sarcoma;
25 colon malignancy; adeno carcinoma, lymphoma, malign carcinoid, melanoma, fibrosarcoma; carcinoma of the rectum; ovarian carcinoma; mama carcinoma; and prostate carcinoma.

The use of minimal invasive surgery has brought with it a reduced mortality and a reduced post-operative infection rate.
30 Classic open abdominal surgery, or laparotomy, for example, may require less operation time than minimal invasive surgery, but involves long post-operative convalescence and a greater risk of infection, e.g. sepsis. One reason why minimal invasive

laparoscopies are on the increase is the drastically reduced amount of time that the patient needs to spend recuperating both in hospital and at home. Laparoscopy also has the advantage that there is a significant reduction in wound scars and in post-operative complications associated with wound healing.

A wide range of laparoscopic procedures are in general use, including laparoscopic cholecystectomy, laparoscopic fundoplication (anti-reflex surgery for gastro-oesophageal disease), laparoscopic treatment of para-oesophageal hernia, laparoscopic treatment of abdominal cysts (e.g. liver cysts removed by cystectomy), laparoscopic liver re-section, laparoscopic appendectomy, laparoscopic treatment of intestinal obstruction (e.g. incarcerated hernias, colon obstruction and massively dilated small bowel obstruction), laparoscopic colo-rectal surgery (e.g. ileosacral re-section, hemicolectomy, sigma-resection, rectum prolapse and rectum amputation), laparoscopic adhesiolysis, emergency laparoscopy (explorative diagnosis), differential diagnosis of appendicitis, acute abdomen, ileus, abdominal trauma, and oncological queries (e.g. to determine whether or not carcinoma is operable).

One aspect of minimally invasive laparoscopies which gives rise to concern, particularly when these are used to combat abdominal malignancies, is the extent to which metastatic growth has been observed. It is now recognised that manipulation of a malignancy can result in a disturbance and release of malignant cells which can then travel to other locations where, if they adhere and start growing, form metastases with predictably unfortunate results. This risk is lower during a classic open laparotomy, for example, so that the whole tumour is carefully excised and removed without transferring any cells to other parts of the abdomen. In a minimally invasive laparoscopy using a trocar,

however, this may not be possible and disturbance of the tumour and its contact with adjacent tissues whilst being removed are inevitable. It has been found that "trocar metastases" are often a result of minimally
5 invasive abdominal surgical procedures, e.g. laparoscopic surgery.

One reason for the frequent observation of metastases following laparoscopic intervention is believed to reside in the use of the trocar tubes or
10 sleeves, the diameters of which may range from 5 to 20 mm. These can either result in damage to malignant tissues or may otherwise come into contact with cell-rich exudate which then drips from the trocar sleeve into the abdominal cavity thereby initiating metastases.
15 To effect the removal of re-sected organs or pieces from the abdomen, a "rescue" bag is introduced via the trocar sleeve. This is particularly so when removing inflamed re-sections or neoplastic tissue in an attempt to prevent contamination of the abdominal cavity by re-
20 sected neoplastic cells or cell threads of the primary tumour.

We have now found that the incidence of metastases following surgery, and in particular trocar metastases believed to be caused by laparoscopic operations, can be
25 reduced if the area affected during the operation and any other internal tissue or organ with which any of the apparatus or tumour comes into contact is instilled with a solution containing taurultam, taurolidine or a mixture thereof.

30 In studies that have been carried out on animal models, a significant suppression in the growth or spread of tumours following instillation of taurultam or taurolidine has been observed.

35 Accordingly, viewed from one aspect, we provide the use of taurultam or taurolidine solutions to prevent or reduce metastatic growth. This is of particular application in preventing or reducing the incidence of

metastatic growth following surgery, and particularly following the use of trocars during minimal invasive laparoscopic surgery, but has general application.

5 Viewed from a further aspect, we provide the use
taurolidine and/or taurultam in the manufacture of a
medicament for the prevention of metastases, in
particular for the prevention or reduction of metastatic
growth.

10 A preferred solution will contain from 0.5 to 3% by
weight of taurolidine, or from 2 to 3% by weight
taurultam, depending on the solubility of the compound.
Solutions containing from 0.5 to 1.0% or 2.0%
taurolidine are preferred.

15 The solutions will generally be made up in sterile
pyrogen-free water and may also contain, for example,
inorganic or other salts or other components to render
them isotonic. Parenterally acceptable polyols may, for
example, also be present since these have been observed
to increase the overall intravenous tolerance of
20 taurolidine. Suitable polyols include carbohydrates,
e.g. hexoses such as glucose and fructose (or mixtures
of these such as invert sugar), pentoses such as xylose
or polysaccharides such as dextran or hydrolysed starch;
glycerol and sugar alcohols such as sorbitol, mannitol
25 or xylitol.

The concentration of the polyol can usefully be in
the range 3-40% by weight. In the case of glucose, the
concentration may be in the range 10-30% by weight,
preferably 20%.

30 The solutions may also contain polyvinylpyrrolidone
(PVP). This may be incorporated into the solutions at a
concentration of, e.g. from 4 to 7% by weight. A
solution containing 5% PVP is preferred. This assists
in solubilising the active substance and contributes
35 also to the oncotic pressure of the solution. The
molecular weight of the PVP should not be greater than
30,000 and is preferably less than 10,000, for example

between 7000 and 9000. Kollidone 17 as sold by BASF is relatively quickly resorbed and excreted renally.

The exact mode of action of taurolidine or taurultam in preventing metastatic growth under these circumstances is still not known. Without wishing to be bound by theoretical considerations, we believe that the taurolidine or taurultam is capable of altering the protein structure surface of the adhesion molecules (receptors) such as I-P-selectine and fibronectine. It is believed that over-expression of molecules such as these, and including also integrine, vitronectine and laminin, are the principal cause of metastatic development since they are believed to provide the malignant cells with the ability to migrate and adhere to other cell surfaces and endothelium, in particular to vascular endothels. The malignant cells then become sedentary, allowing themselves to grow and further develop (metastases). Once developed, such cells are able to reach every organ either through the haematogenic or lymphatic channels (formation of metastases).

It is believed that the taurolidine or taurultam modifies the surface structure of the malignant cell in such a way that over-expression of the adhesion molecules is reduced. As a result, adhesion of the malignant cells to other cell surfaces and endothelium, e.g. to endothels, is reduced or does not occur before the cell itself dies. The active agent is not believed to have any direct cytotoxic effect on the malignant cells. Taurolidine or taurultam is also believed to prevent high cytokine levels, e.g. IL-1 β , in peritoneal fluid, which in turn prevents tumor cell proliferation and adhesions. The taurolidine or taurultam is thus being used essentially prophylactically.

The taurolidine or taurultam solution may be used simply by instillation, as an aerosol (a nebulised solution of taurolidine or taurultam) and/or by

intravenous infusion. When being used in conjunction with a surgical procedure, it may be administered either prior to, during or after the surgical procedure being carried out. If used as an instillation to irrigate the surgically affected area, it will be administered intra-operatively or before closure of the surgical incision. In minimal invasive surgery, the solution can be passed through the trocar tubes or sleeves.

In general, in preparation for laparoscopy the abdominal wall is lifted. This may be achieved either by insufflation (pneumoperitoneum) or mechanically. Special instruments are required to raise the abdominal wall without causing damage to the intestinal loops. A Veres needle having an opening on one side through which a gas may enter the abdominal cavity is generally used for preparation of the pneumoperitoneum. Gases conventionally used for insufflation include N_2O , CO_2 and helium which may be introduced into the abdominal cavity at a rate of up to 1 litre/min. Depending on the patient's body size and tissue tension, between 3 and 5 litres of CO_2 gas may be required. For diagnostic laparoscopy under local anaesthetic, N_2O is preferred since, unlike CO_2 , this does not irritate the peritoneum. Whilst not wishing to be bound by theory, it is believed that this irritation could be one of the reasons for the more frequent appearance of metastases observed when using CO_2 .

A metal suspension bar is conveniently used to lift the abdominal wall mechanically. Once inserted into the abdomen, special hooks are attached to the suspension bar and the abdomen is then raised using a chain and suspension scale.

According to the type of surgical procedure, for example in minimally invasive abdominal surgery, from 100-1000 ml, preferably from 100-250 ml, of a 2%, 1% or 0.5% taurolidine solution can be instilled at body temperature and allowed to remain in the abdominal

cavity after the end of the operative procedure, and before extraction of the gas used in the pneumoperitoneum (which enlarges the abdominal cavity and with which the laparoscopy starts) and final removal
5 of the trocar.

For the prophylaxis of post-operative complications, particularly trocar metastases, a 2% Taurolin, a 0.5% Taurolin-Ringer or a 2-3% taurultam solution may be used. Conveniently, the abdomen is
10 rinsed with such a solution using a rinse-suction tube. A 5 or 10 litre rinse bag is filled with the desired rinse solution (isotonic saline or ringer solution) and hung at a height of approx. 2 m. 1-2 litres of rinse solution are then introduced through the rinse-suction
15 tube. Following a short contact time (sufficient to ensure that the intestinal loops are completely covered by the rinse solution) the solution is then suctioned off. In cases of severe inflammation, the rinsing solution will appear opaque such that abdominal
20 visibility using the optic and camera is poor. In such cases, this rinsing procedure must be repeated until the liquid in the abdomen is clear and translucent.

When the rinsing procedure is complete and the solution is clear, the rinse bag is then filled with 250
25 ml 2% Taurolin (pre-warmed to 37°C) which is allowed to flow into the abdominal cavity. Finally, a drain is inserted before closure of the abdomen. In severe cases, e.g. severe peritonitis, it is possible to instill (and in some cases to leave) up to 1000 ml
30 Taurolin 2% solution within the abdominal cavity. In place of a 2% Taurolin solution, 1-1.5 litres Taurolin-Ringer 0.5% solution or a 2-3% taurultam solution may be used.

In patients with malignant tumours it is
35 particularly advantageous to additionally administer Taurolin 2% intravenously through a central catheter as a drop infusion, e.g. at a dosage of 4 x 250 ml per

day). If necessary, the drop infusion may be continued for 2 - 3 days following surgery.

Alternatively, the 2% Taurolin solution may be instilled and suctioned off using a pressure-rinse apparatus. Another variation is to attach a pressure-cuff to the rinse bag whereby suction may be carried out using a suction-off apparatus. It is also possible to use an infusion pump as an alternative to instillation.

In a preferred embodiment of the invention, the taurolidine or taurultam solution will be used simultaneously with heparin. The use of heparin alone has not been found significantly to influence metastatic growth but the use of heparin in conjunction with taurolidine, administered either in combination or separately, has been found to give a significant, synergistic effect. The desired dosage of heparin depends on the result of the blood coagulation test. Thus, this will vary from patient to patient but can nevertheless be readily determined by those skilled in the art. An average dosage of heparin can be expected to be in the range of from 230 to 625 I.U. heparin-Na/kg bodyweight. In general, 5000 I.U. heparin-Na might be administered up to 2 hours prior to surgery.

For use in laparoscopic surgery, standard-heparin-sodium or standard-heparin-calcium may be added to the taurolidine solution immediately prior to application. Alternatively, low molecular weight heparin may be used. Typically, 200-500 ml 0.5-1.0% Taurolin in isotonic saline or Ringer-solution may be administered in combination with 1000-5000 I.U. heparin via a trocar tube.

The taurolidine-heparin solution may conveniently be applied under pressure, e.g. approx. 10-12 mm Hg, by means of a micro-pump. Administered in this way, the solution enters the abdominal cavity as an aerosol, resulting in a more widespread application of the solution to all exposed interabdominal (interior and

lateral) surfaces during surgery. Administration of the solution as an aerosol also results in an increased efficacy during pneumoperitoneum with carbon dioxide.

5 In an alternative embodiment of the invention, the taurolidine or taurultam solution may be used simultaneously with hyaluronic acid, e.g. with a 0.1% hyaluronic acid sodium salts pharmaceutical grade solution, preferably having a molecular weight of 2.5×10^6 Da.

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Test Procedure

To prevent intraperitoneal tumour growth and trocar metastases caused by laparoscopic operations, the effect of taurolidine and heparin were investigated on the growth of colon carcinoma cells (DHD/L12/TRb) in vitro, as well as in rat models. After incubation of the cells with heparin, taurolidine or both substances there followed the in vitro determination of the growth kinetics of the cells. A second experiment followed on rats (n=60) following intraperitoneal application of tumour cells and subsequently the development of a pneumoperitoneum for 30 mins. The rats were randomised into 4 groups:

- 25 I Tumour cells
II Tumour cells + heparin
III Tumour cells + taurolidine
IV Tumour cells + taurolidine + heparin

30 Results

Where the tumour growth in vitro was not affected by heparin, a significant suppression of growth was observed with taurolidine and taurolidine/heparin. In vivo, however, the intraperitoneal tumour weight compared to the control group (596 ± 278 mg) was reduced both with the instillation of heparin (298 ± 155 mg) as well as with taurolidine (149 ± 247 mg). The

combination of both substances caused a further average
tumour weight reduction of $(21.5 \pm 36 \text{ mg})$. The
development of trocar metastases could be significantly
suppressed using either taurolidine alone, or the
5 combination of taurolidine and heparin.

The following non-limiting examples serve to
further illustrate the invention.

10 Example 1 - laparoscopic procedure

In a typical abdominal procedure, which should not
be considered as limiting, a 0.5% taurolidine Ringer
solution at body temperature is rinsed through the
suction rinse tube under minimal pressure intra-
15 operatively.

According to the extent of surgical invasion, from
100-250 ml 2% taurolidine is instilled at 37°C and
allowed to remain in the abdominal cavity on conclusion
of the operative procedure.

20 Example 2 - laparoscopic procedure

A typical abdominal procedure may be carried out in
accordance with Example 1, except that the 2%
25 taurolidine solution is replaced by a 500 ml 0.5%
taurolidine Ringer solution used in combination with
2500 I.U. heparin. This solution is instilled into the
abdominal cavity via drains which are then clamped for 2
hours.

30 Example 3 - laparotomy (partial pancreatectomy)

In a typical treatment of pancreas head carcinoma,
the operation site is meticulously rinsed with approx.
35 500-1000 ml warm (37°C) 0.5% Taurolin-Ringer solution.
After 10 minutes contact time, the solution is suctioned
off.

Every 20 minutes the operation site is moistened with 100-200 ml 2% Taurolin solution using a large calibrated curved syringe.

5 After 10-15 minutes contact time the solution is suctioned off. Before final closure of the abdominal wall, 250 ml Taurolin 2% solution* (with heparin added according to the blood coagulation results) is instilled.

10 * Alternatively, 2-3% taurultam may be used.

Example 4 - laparotomy (radical mastectomy)

15 In a typical treatment of mamma carcinoma (radical mastectomy), the operation site is rinsed intra-operatively every 20 minutes using 200 ml Taurolin 2% solution. If possible, a 10 minute contact time is permitted by lifting the surgical drapes thereby preventing the rinse solution from draining away too quickly.

20 The operation wound is then closed and drained.

Additionally, intraoperative per drop infusion of 250 ml 2% Taurolin solution is administered via a central catheter (dosage: 4 x 250 ml per 24 hours).

25

Example 5 - laparoscopic procedure

In a typical abdominal procedure, a taurolidine solution is administered in the form of an aerosol. This may be achieved through the use of a micro-pump which is situated between a gas (e.g. CO₂) supply and the abdominal cavity in which surgery is to be performed. A tube is used to carry the aerosol into the trocar tube or sleeve. The taurolidine solution may be administered continuously as a spray during abdominal surgery, e.g. at a rate of 100 to 200 ml per hour.

Example 6

Cancer patients are selected who are undergoing major abdominal cancer surgery. Two groups are patients are studied. Group A receives 250 ml taurolidine 2% solution drop infusion for two hours, followed by two hour intervals, a total of four times for a total administration of 1 liter taurolidine 2% solution. The taurolidine solution is administered intravenously through a central line prior to surgery. Group B receives saline vehicle control according to the same schedule. Taurolidine 2% solution is administered for two further doses post-operatively at six hour intervals. Antibiotic prophylaxis cover is given as Augmentin 1.2 g at induction and a further two doses given post-operatively. The effects of taurolidine 2% solution administered intravenously to cancer patients, including colon, rectum, pancreas, stomach and lung cancer patients, on angiogenic growth factors, were as follows: Reduction in serum vascular endothelial growth factors (VEGF) from 500-600 pg/ml to 350-360 pg/ml, Reduction of serum transforming growth factor (TGF- β) from 2,300-2,350 pg/ml to 990-1,050 pg/ml six hours post-operatively and to 1,700 pg/ml 24 hours post-operatively. Taurolidine 2% solution administered intravenously also decreased serum soluble adhesion molecules following surgery in cancer patients, including sE-selectin, sP-selectin and sVCAM-1.

Example 7

The effect of Taurolidine was examined on the growth of a rat metastatic colorectal tumor cell line (DHD/K12/TRb) *in vitro* and *in vivo*.

In the *in vitro* experiments, DHD/K12/TRb cells were incubated with 5, 10, 15, 25 μ g/ml of Taurolidine. Cells incubated in culture medium alone were used as controls. Cell proliferation, cell viability, cell death, and cell apoptosis were measured using commercially available techniques.

In the *in vivo* experiment, BD IX rats were randomized into 2 groups (n=10/group). Group A (control) underwent laparotomy, instillation of DHD/K12/TRb tumor cells intraperitoneally followed by phosphate buffered saline (PBS). Group B received Taurolidine (100 mg/kg) instead of PBS. Animals were sacrificed after 24 days

and tumor burden assessed by counting the number of tumor nodules in the peritoneal cavity.

Incubation of the tumor cells with Taurolidine resulted in a 4 fold decrease in proliferation rates ($25 \pm 4\%$ v $100 \pm 28\%$ for controls) and a 4 fold increase in cell necrosis as demonstrated by the increase in LDH release ($403 \pm 28\%$ v $100 \pm 26\%$ for controls), at a Taurolidine concentration of 25 $\mu\text{g/ml}$. A dose dependent decrease in cell viability also was observed. In the *in vivo* study, local Taurolidine administration resulted in significant decreases in tumor burden (3 ± 1 nodules in Group B animals vs 649 ± 101 nodules in Group A animals). Taurolidine thus inhibits the growth of a rat metastatic colorectal tumor cell line *in vitro* and *in vivo* and prevents or reduces peritoneal metastases.

Example 8

The human colon cell lines SW 480 (primary), SW 620 (metastatic) and W 707 (metastatic) were incubated with the following: culture medium (control), taurolidine at 5, 10, 25, 50 and 100 $\mu\text{g/ml}$ doses, and 5-Fluorouracil (5-FU) at 5, 10, 25, 50 and 100 μM doses. Cell proliferation, apoptosis and cell cycle were assessed.

There was a significant decrease in tumor cell proliferation at 24 hours as shown in the table (results as % of control). There was no significant increase in taurolidine-induced apoptosis and taurolidine did not alter the phases of the cell cycle. There was an increase in LDH release ($p = .0011$), which correlated with inhibited tumor proliferation. Taurolidine was also compared with 5-FU and was found to be superior in inhibiting cell proliferation ($p = 0.001$) and augmented the effects of given doses of 5-FU ($p = 0.0001$).

PROLIFERATION	Control	T 5 µg/ml	T 10 µg/ml	T 25 µg/ml	T 50 µg/ml	T 100 µg/ml	
SW 480	100	100.10 ± 0.18	101.68 ± 2.17	87.93 ± 2.95 *	53.55 ± 3.84 *	14.62 ± 4.40 *	p = .0001
SW 620	100	89.42 ± 1.85	90.22 ± 1.55	58.10 ± 14.86 *	25.01 ± 8.87 *	7.8 ± 1.35 *	p = .0001
SW 707	100	97.33 ± 4.06	88.48 ± 9.39	62.37 ± 24.27	36.81 ± 15.36 *	6.02 ± 0.26 *	p = .0009

ANOVA (* vs controls)

Taurolidine inhibits the proliferation of these three human colon cell lines at doses within the therapeutic range and proved to be more effective than the above doses of 5-FU and it also enhanced the effects of 5-FU. It would appear to act as a direct cytotoxic agent on the tumor cells.

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